SELF-ORGANIZED AIR TASKING: EXAMINING A NON-HIERARCHICAL MODEL FOR JOINT AIR OPERATIONS

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Abstract

The hypothesis of this paper proposes that it is possible to structure a non-hierarchical approach to air tasking in the conduct of Joint air operations. For the private sector, advances in information and communication technologies have led to innovations in organizational structures in order to know more across the enterprise. However, the application of these "value network" principles has not been fully applied to the processes upon which the U.S. organizes for Joint force operations. A non-hierarchical model is constructed for the tasking of air assets in order to test an agent-based approach to the servicing of targets in an air campaign, using agent-based simulation techniques and models established by Epstein & Axtell (SugarScape) within the Santa Fe Institute's Swarm agent modeling environment.

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Hierarchy and Air Tasking

For U.S. military operations, the preferred organizing principle is the hierarchy. The orchestration of airpower, with its synchronization of target intelligence, aircraft weaponeering,[1] launching and recovery operations, flight paths, fighter escorts to engage enemy aircraft, positioning of air-to-air refueling resources – is no exception to this preference, although the centralized command and control of air operations is a relatively recent development in the history of U.S. military air operations. Driven by past errors which have been traced to a lack of central control, the Air Force has largely succeeded in crafting a hierarchy for air operations: the Joint Force Air Component Commander (JFACC), which has operational control of all U.S. aircraft engaged in a military conflict, regardless of Service affiliation. This is heralded as an improvement to the effective and efficient use of airpower, and was tested on a large scale for the first time in 1991's Operation Desert Storm, also referred to in the literature as the Gulf War. Winnefeld and Johnson found that: "The mode that has worked best to date, as confirmed by the experience of the Gulf War, is for one component commander to act as the lead commander and be given tactical control of sorties from the committed assets of the other services. This functional air component commander should have a joint staff and senior representatives of the coordinated components' forces on duty as his air operations center, and in some cases those representatives should be at the deputy functional component commander level (150)." While naval aviation forces are also subject to the JFACC, and have developed operational

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[1] The loading of a specific weapon onto a specific aircraft. Certain aircraft are optimized for the delivery of certain weapons, and those weapons in turn have varying degrees of effectiveness against certain types of targets. The careful planning of which type of weapon, aboard which plane, will hit which target, is the focus of the Master Air Attack Plan.

concepts for a "JFACC Afloat," these air assets have historically functioned in a decentralized manner.

A Non-Hierarchical Air Campaign

One question that arises from this review is: How does one reconcile the insights of organizational theory, and its contributions to the modifications or elimination of the hierarchy, with the movement towards increased centralization for U.S. military air operations? Might the increased effectiveness and efficiencies noted earlier for "learning network" organizations be applied within the context of U.S. military air tasking? If there were a way to retain centralized command of U.S. airpower while introducing a decentralized execution, is the current approach to resource allocation optimal for operating within this paradigm? It may be that allowing for a decentralized control of airpower – allowing aircraft to use advanced information and communication technologies to (possibly) more effectively and efficiently engage targets, in effect, to self-organize to achieve objectives – is one way in which the benefits from these technologies can be realized within the context of U.S. military operations.

This research is an existence proof to study the feasibility of a self-organizing air campaign[2] for Joint air operations. Using agent-based modeling techniques, a simulation is constructed to test the concept of instituting an self-organizing system – wherein constructs of pilots, aircraft, weapons, escorts (all acting as agents) – bid on fixed/known as well as mobile/emergent targets in a Joint air campaign. By specifying the "best" weapon for a particular target, and allowing aircraft to communicate their capabilities and position to nearby aircraft, the objective is accomplished of pre-planned aircraft tasking: allowing the most appropriate aircraft to attack the target. This objective is achieved without a pre-planned air tasking order (ATO), which specifies before the day's activities which aircraft will strike which target.

[2] This term is used throughout the paper, and refers to the planning and execution of airpower used in support of objectives in a military conflict.

In examining the feasibility of a self-organizing air campaign, this paper implies that the partial decentralization of tasking for air assets may also be feasible. Many historians will question this feasibility, particularly following the experiences in the Vietnam conflict, which predate the establishment of Joint air planning. In Vietnam, excessive geographic decentralization of air planning often meant the lack of coordination among Services or areas of responsibility (AORs) within the theater of operations. With no single air commander, with authority over Air Force and Navy fixed-wing operations or Army helicopter missions, it was difficult to manage assets for strategic theater-wide effects. Also, targets could appear on the air tasking lists of more than one Service, resulting in redundant capability expended on some targets. With the advent of improved information and communication technologies, decentralization may no longer mean a lack of coordination. Information technology has a democratizing effect, where the marginal transaction cost (in terms of money, time, and effort) of delivering information is sufficiently low as to remove barriers to long-distance, real-time coordination mechanisms.

Motivation

"Information to the warfighter." This call to arms characterizes much of battlefield command and control (C2) efforts since Desert Storm. We have "intelligent" weapons systems, with "smart" guidance packages. We tell weapons where to detonate, and loose them at targets. "Fire and forget" is a term often used among air warriors to describe these techniques used to deploy "smart" bombs and missiles. The pilot, however, must still work according to a script worked out hours earlier. We are still using air assets as we did fifty years ago – manned aircraft working to a script, and releasing ordnance over a target as described in the ATO. As we increase the information available to the warfighter, perhaps new ways of assigning weapons to a target can be found. The recent campaign in Afghanistan is a departure from the scripted approach, but the scarcity of the target set may not be representative of future theaters. Likewise, while the use of patrolling bombers and unmanned combat air vehicles (Predators with Hellfire missiles) represent new uses of existing air assets, it is too early to conclude that the U.S. has abandoned the centralized, scripted approach to an air campaign.

In business, the increase of available information, when coupled with a change in process or workflow, may lead to increased efficiencies and effectiveness of individual agents in an enterprise. Likewise, we can envision situations where the increase in information may result in inefficiencies where workflow or processes are not changed to accommodate the glut of information. In complex adaptive systems, the agents who can adapt their approach to a changing environment help sustain the system at "the edge of chaos" – the most lucrative formation for the achievement of system objectives. For the warfighter, then, we should investigate new processes, ones that allow adaptation to a changing environment, in hopes of discovering new efficiencies and increasing the effectiveness of warrior assets.

Rationale

With the common objective of providing more and faster information to the decision-makers/stakeholders in a conflict, the deployment of technologies alone will not be sufficient to realize the potential benefits. Builder, et al., provide a strong case for the development of a concept for command and control that maximizes (or reaches beyond) available technology – rather than treating the command and control processes as simple implementations. Given the process and organizational innovations in the private sector following the incorporation of advanced information and communication technologies, it behooves the researcher in the public sector to consider similar innovations for processes within the public sector.

This paper seeks to initiate a body of work that may lead to a more effective integration of weapons platforms (manned and unmanned aircraft) in Joint air operations. In many ways, the lessons of Operation Desert Storm (ODS) were optimistic, in that an enemy presented the Coalition forces with months of preparation time, the ability to therefore marshal half a million U.S. troops and thousands of aircraft, and time to plan a devastatingly synchronized attack to its ground forces and strategic centers of gravity. Winnefeld, et al. refer to the Persian Gulf as a "near-ideal theater for deploying a large expeditionary force (26)." Future conflicts may force air planners to work with fewer weapons platforms.

Given that the U.S. military is investing heavily in information technologies in order to provide heightened visibility into the battlefield situation (enemy and friendly force capabilities, vulnerabilities, intention, and location); the persistence of a scripted ATO that relies on 24-72 hours-old information to make targeting decisions is anachronistic. We seek here to apply processes to air targeting that leverage the future battlefield, by allowing information about the battle to be immediately incorporated into the decisions regarding which aircraft strike what targets.

Hypothesis

Current organizational structures for Joint air operations are potentially inefficient, when considered within the context of the possibilities offered by advanced information and communications technologies. These advances in technology are accompanied by innovations in organizational structures, at least in the private sector, in order to know more across the enterprise. The Department of Defense has studied these innovations and extended them across the acquisition community as best principles for supply chain integration and management. However, the application of "value network" principles has not yet been applied to the processes through which we organize for joint force operations. The hypothesis for this work can be stated thus:

> ***It is possible to structure a feasible non-hierarchical approach to air tasking in the conduct of Joint air operations.***

A simulation is constructed of a non-hierarchical, or self-organizing, assignment of targets within an air campaign, using agent-based modeling, as an existence proof. Allowing for the semi-autonomous interaction of aircraft/weapons/support packages as they bid for targets would represent a new approach to this information-intensive process, currently accomplished through manual planning (where each target is assigned to a specific aircraft with a defined weapons suite). The hypothesis is rejected if the self-organizing air tasking model is infeasible.

The degree of autonomy granted to agents is an issue for organizational theorists and sociologists. How 'necessary' is a directed hierarchy in an enterprise where each stakeholder is committed to a common core of principles, understands the mission, and has the information necessary to maximize their effectiveness within the enterprise? The implied question here of 'necessity' overlooks the sociological view (Fukuyama 1999) that hierarchies do not exist solely on the basis of transaction cost economics; instead, there are indications that human beings engaged in a common endeavor will often prefer a hierarchical organization to complete agent-level autonomy.

This work, however, does not address the social feasibility of a partially decentralized approach to air tasking – we leave the political and human teaming variables to future research. The metrics of feasibility here are intentionally narrow, relating only to the achievement of operational objectives, as this represents the first step to investigating the potential promise of decentralized, self-organizing air campaigns. The hierarchical organizational structure may be reviewed in light of emerging information and communication technologies, but there are sound principles that present barriers to decentralization, principles that must be addressed in any non-hierarchical model. The key barrier for air operations in conflict is time-to-decide. Time is the key variable here, as the increased time to assign and decide in any market-based system for assignment of targets may reduce flexibility and effectiveness. Feasibility here, then, is assessed according to the following questions:

1. Are the targets struck quickly, that is, within a reasonable amount of time after becoming candidates to the target list?

2. Are the targets struck effectively in this construct – with sufficient capability, as needed to damage/destroy the target?

Metric 1 is related to the inherent inefficiencies noted in agent-based simulations of economic activity (Epstein & Axtell); while metric 2 captures the normative validation of the model: Does it resemble a reasonable use of airborne attack assets against targets?

Agent-Based Modeling and Complex Adaptive Systems

In suggesting a partial shift in the organization of air operations, to allow for the decentralized air tasking, the air campaign should be viewed as a self-organizing system, wherein agents purposefully work to achieve local objectives. This is in keeping with the use of agent-based modeling to examine whether local rules can be written for semi-autonomous or autonomous agents that accurately reflect the design of a grand strategy. If we can enable agents to execute based on fluid local situations, and achieve the same adherence to the grand strategy as is found in strict centralized execution, we may realize a greater flexibility and possibly therefore increase the chances for success.